ALLEN GROUP
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PATTERNS & INTERPRETATIONS

This guide is intended to serve as a reference to interpreting the primary and secondary patterns displayed on your "scope." The explanation to follow will discuss each pattern separately, area by area, and show which parts of the primary or secondary circuit are generally affecting that area of the pattern.

Also, in Section 4, there are a number of typical pattern defects which will be identified as to the most likely cause of the defect with further reference back to the pattern area explanation.

We will begin with an explanation of the "scope" and the engine ignition system followed by the primary and secondary pattern explanation, and then the typical pattern distortion and their cause.

SCOPE

The oscilloscope is an instrument which allows the diagnostician to check the engine ignition system while the engine is running.

The oscilloscope or "scope" as we will call it, is essentially an electronic device for measuring rapid changes in voltages. The primary and secondary circuit voltages are changing in relation to the engine point opening and closings and the circuit components.

In the case of electronic ignition systems, the electronic module performs the same function as the ignition points.

The circuit voltages are impressed on the viewing screen and "paint a picture" of these variations.

Analyzing abnormal conditions shown on the viewing screen can lead us to the component or components causing the problem.

IGNITION SYSTEM

The ignition system is made up of two basic circuits. The primary circuit consisting of the battery, ignition switch, ballast resistor (if used), primary coil winding, the distributor breaker points and plate (or electronic module) and a return to the battery.

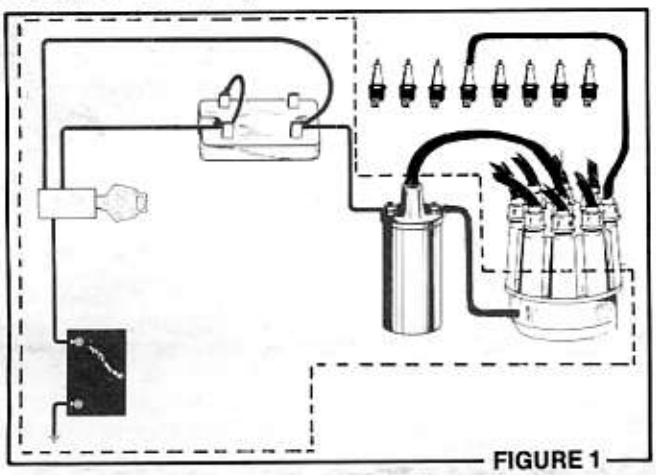


FIGURE 1

The secondary circuit consists of secondary coil winding, distributor rotor and cap, high tension wires, spark plug wires and spark plugs.

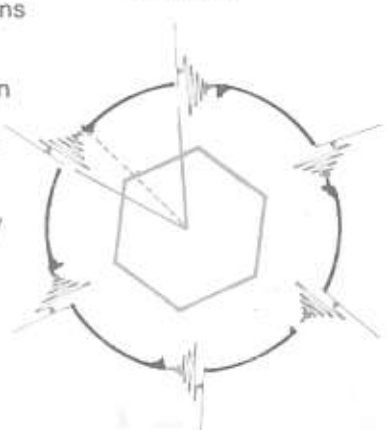
Figure 1 is a diagram showing the basic ignition circuit, both the primary and secondary.

All components within the dotted (blue) line comprise the primary circuit and those components outside of the dotted line comprise the secondary circuit. The vehicle ground is common to both the primary and secondary circuit. (See Figure 1).

When the ignition switch is turned on the primary current path is through the ammeter, ignition switch, ballast resistor, primary coil winding, breaker points to ground and back to the battery as long as the ignition points remain closed. During this time, a strong magnetic field is developed around the coil. When the ignition points open, the magnetic field will collapse due to the sudden interruption of current. As a result a high voltage is induced into the secondary winding where this voltage is impressed through the high tension wire, rotor & cap, spark plug wire and creates a spark across the plug electrodes.

The area between the start of one set of oscillations to the next set of oscillations is the firing pattern for one cylinder. During that time the points open and close. The points remain open for approximately 40% of 60° as in the example and are closed for approximately 60% of the time.

FIGURE 2



The blue area shows the point open time while the black area shows the point close time. The point close time is termed dwell and is important to proper operation of the ignition system.

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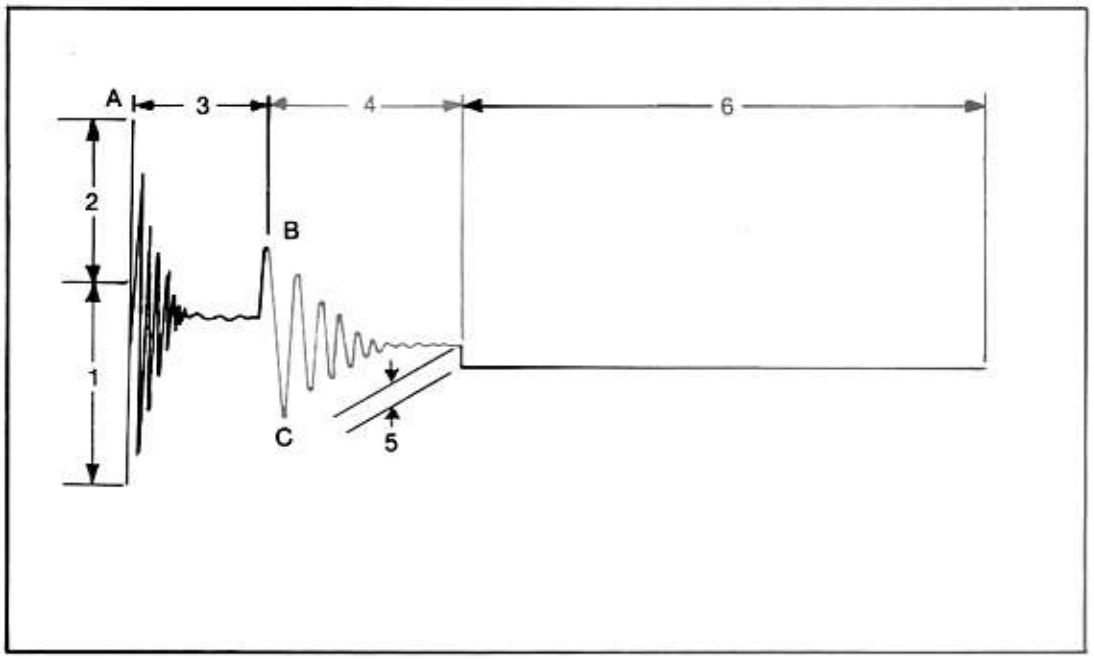
PRIMARY PATTERN

1. Point Opening
2. Primary Voltage (Inductive Kick)
3. Primary Coil Oscillations
4. Coil/Condenser Oscillations
5. Point Closing
6. Dwell

A. Primary Resistance
B. Coil Energy
C. Condenser Energy



1. Point Opening

The point opening should always be clean and sharp.

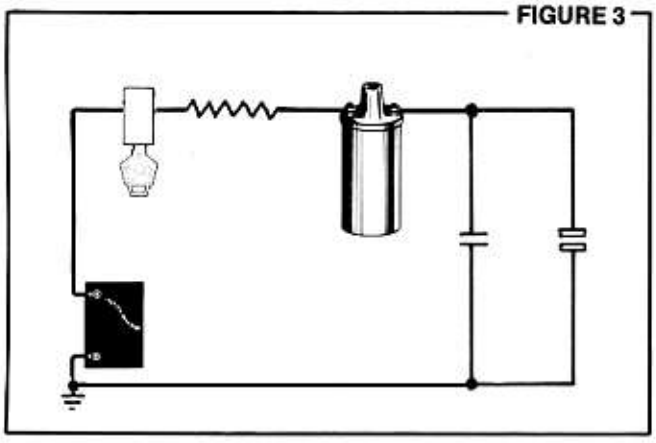
At this time, the ignition point contacts are beginning to separate due to the push on the breaker arm lever by the cam lobes. Also, at this time, the magnetic field is beginning to collapse causing the primary coil voltage to rise towards its maximum level.

If the voltage rise is faster than the point contact separation, the primary voltage will reach a level sufficient enough to cause a spark to be developed across the point contacts. It is the job of the condenser to keep the voltage rise slowed down adequately until the engine points have separated far enough to prevent an arc.

A condenser that is open or one of too small a value will not do its job. Consequently, arcing is likely to occur.

By the same reasoning, a condenser that is partially shorted or one of too large a value, will slow down the voltage rise too much were the result will likely be too little energy (power) developed in the coil. A further explanation of under-capacity and over-capacity condenser is to be found in #4.

FIGURE 3



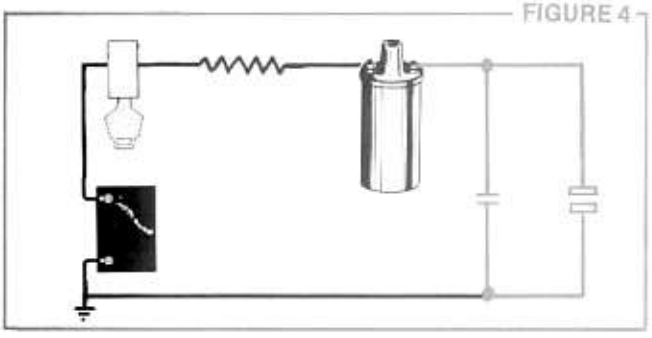
The primary circuit diagram shown in Figure 3 shows the components most likely to effect the point open area.

2. Primary Voltage

This area can be termed "primary resistance." It is the inductive kick provided by the primary winding when the coil current is interrupted.

The height (Point A) of this oscillation is determined by the amount of coil current just before the points open. The current in the circuit depends on the voltage (pressure) and the resistance to this pressure as the current completes its path around the primary circuit.

FIGURE 4



The primary circuit shown in Figure 4 shows the components and connections most likely to cause high resistance (lower than normal height at Point A) in the circuit.

Keep in mind voltage pressure is also instrumental in making primary current. Be sure the regulator voltage is correct.

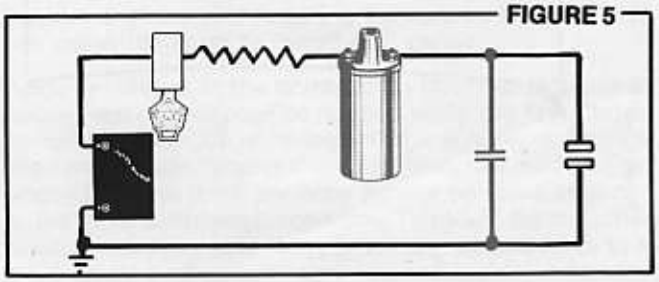
3. Primary Coil Oscillations

During this time the energy in the primary winding is being decayed due to the continuous collapse of the magnetic field. These coil oscillations occur as the primary energy is dumped into the condenser. At this same time the plugs in the secondary circuit are being fired. Consequently, these oscillations will continue only as long as the spark plug fires.

4. Coil/Condenser Oscillations

Not all of the energy in the coil is drawn off while the spark plug fires, therefore it is the responsibility of the coil and condenser to dissipate the remaining energy in the circuit before the engine points close.

FIGURE 5



At this time the remaining energy in the coil is discharged into the condenser (Point 3). The condenser will momentarily store this energy and then push it right back into the coil (Point C). This action is again repeated until all of the energy is used up. (Each time one of the other components gives up its stored energy the strength weakens. Compare this to a pan of water which has been "sloshed" from side to side. Once the pan is placed to rest the water will splash from side to side, each time with less power, until it settles down). The coil condenser oscillation should settle down before the points close. Otherwise the energy will be dissipated in the form of an arc across the points when the contacts get close enough together (Obviously an undesirable condition).

5. Point Close

The points close should always be clean and sharp. This assures us that the point contact area is coming together squarely and tightly.

Misaligned points, loose contacts or bouncing points are mechanical defects which are undesirable and will likely cause problems of wear or sudden failure. These problems are corrected by replacement of the points.

However, more can be known about the distributor condition by viewing this area. Theoretically, the points should always close at the same place for each cylinder.

If the point close area varies more than 5° , a strong suggestion that one of the following is at fault.

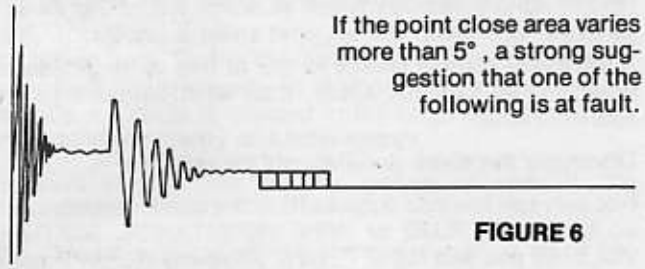


FIGURE 6

1. Worn Cam
2. Bent Distributor Shaft
3. Worn Upper Bushings.

Excessive variation at point close time will also produce timing variations from cylinder to cylinder.

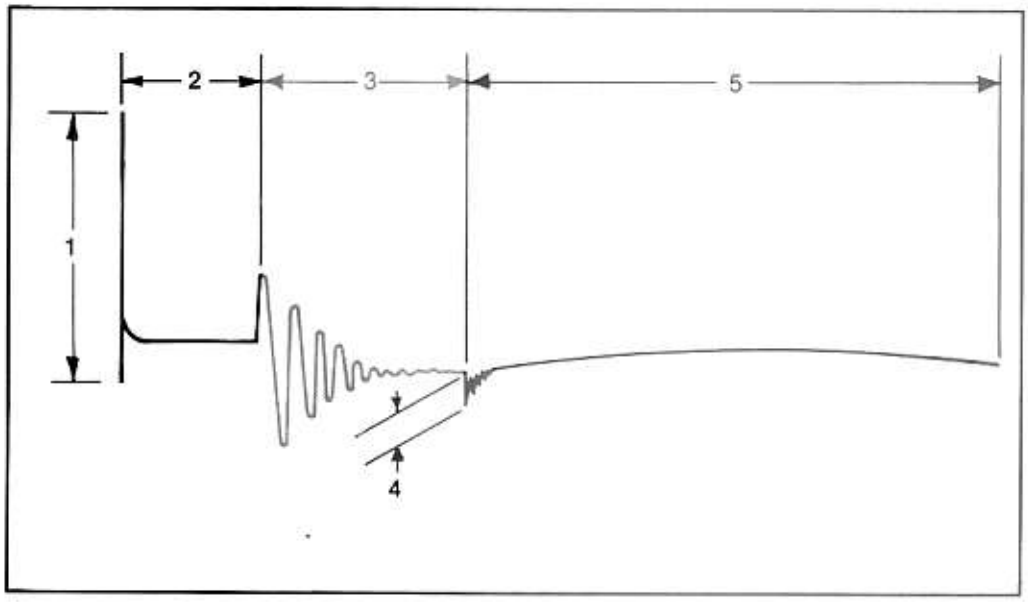
Variations of this nature are not normally noticed with electronic ignition systems. If encountered consult the manufacturers specifications.

1. How do the points open?
2. How much energy is developed?
3. Are the coil oscillations uniform?
4. Can we "get rid" of the remaining energy before the points close?
5. How do the points close?
6. Do the points close and remain closed?

The conditions of the primary circuit directly effect the secondary circuit. The problems of the primary circuit are generally common to all cylinders. When a problem shows in only one primary cylinder, the likely cause will be due to the distributor cam.

SECONDARY PATTERN

1. Plug Firing Voltage
2. Plug Firing Time
3. Coil/Condenser Oscillations
4. Coil Build-Up
5. Dwell



1. Plug Firing Voltage

The initial secondary spike is the amount of voltage necessary to start a plug spark.

As the ignition points (or electronic module) block the primary coil current, a large voltage is induced into the secondary coil (Typically 25-30 KV).

However, only a certain amount of this voltage will be necessary to cause a spark to occur from one plug electrode to the other.

Since the voltage has to jump a gap existing between the two plug electrodes, the distance between them will affect how much voltage will be required. Also, the amount of conductive material (fuel) within the combustion chamber will affect how much voltage will be required.

Another factor affecting plug voltage requirement is electrode temperature.

These three conditions together will affect the total demand from the voltage supply.

It is obvious that if the demand exceeds the supply the spark plug will never fire.

Analysis of this portion of the secondary pattern will depend largely on the demands of ALL of the spark plugs.

It is not so important that we know precisely "how much voltage" but rather that we observe "how much voltage difference" from one cylinder to the next.

Most older vehicles used fuel mixtures that were much richer than the emission controlled engines of today. Therefore, since richer mixtures provide more conductive material between the spark plug electrodes, the spark will occur easier (with less demand) than leaner mixtures (more demand).

Also with changing times, the spark plug gaps have changed. Some engines today use much wider gap (.055) as high as .080.

Since plug gap distance has increased, the spark plug voltage demand has also increased.

Also, with leaner fuel mixtures, engine combustion chamber temperature has increased. Spark transfer from one electrode to the other is easier (less demand) which has a tendency to offset higher demands as a result of the leaner mixtures. However, the temperature variations are neglible with respect to fuel mixture changes when related to voltage demand.

2. Plug Firing Time

This area is the time that the spark plug is firing (spark duration).

The statement that a flamefront will self-propagate once the spark plug gap is ionized may be correct for older vehicles with rich mixtures.

However, with leaner mixtures encountered on late model engines, the combustible mixture is scarce. As a result fuel will start to burn with the beginning of the spark but may not continue to burn if the spark immediately stops.

It therefore becomes very important to sustain the spark across the electrodes for the entire duration of combustion. If spark duration were not important, then there would be no need to produce 25 KV out of the secondary coil if 12 KV would be sufficient.

Almost all of this extra energy goes into keeping the spark plug firing.

If the initial reserve energy is low or if it is lost in some other source than the spark, then what happens to the spark duration?

Obviously the spark duration will be reduced.

Not only can low coil output affect the spark duration, but so can HIGH PLUG or WIRE RESISTANCE, MIXTURE VOLUME and MIXTURE FLOW. Anything that will raise energy demand or cause energy to be shunted elsewhere.

High plug or wire resistance may not affect the voltage demand of the spark plug to start the spark, but it will turn some of that energy into heat loss leaving the plug with less power to sustain the spark. While wide plug gaps will require more voltage to start the spark and a greater amount of energy to keep it going. Since only so much energy is available, it is used up faster. The result is reduced firing time.

When the fuel mixture starts to burn out, it becomes increasingly harder for the remaining energy to keep the spark going. As a result the required voltage starts to rise and the plug quickly ceases to fire.

When one or some, but not all, cylinders firing lines slope up to the right and firing time shortens, there is an indication that those combustion chambers receive less fuel (since fuel is conductive). Since valves control the fuel volume, restrictions in the intake or poor seating of an exhaust valve (drawing burned fuel back into the combustion chamber and reducing the volume of fresh fuel) can cause the spark to "snuff out" earlier.

Also, turbulence in the combustion chamber (somewhat normal and desired) can be noticed along the firing time. An erratic condition showing voltage spiking or voltage rises could mean "pockets of void" (lean fuel mixtures) or open EGR valve (both perfectly normal on some engines) or the more detrimental condition: "air leak". On the other hand, excessively long firing times are not likely due to a great amount of energy, very low resistance, extremely rich mixtures or very small plug gaps, but more likely due to no plug gap at all. Carbon fouled plugs will lengthen the firing time since, first of all, little energy is required to jump the small gap of the rotor (consequently a low initial voltage requirement) and no spark is developed across the plug. The energy follows the carbon to ground with little effort. The only limiting condition to the duration is the rotor air gap.

3. Coil/Condenser Oscillations

Not all of the energy in the coil is used up in the spark. The remaining energy is dissipated through the primary circuit (Refer to Primary Pattern #4).

4. Coil Build-Up

During this time the ignition points have closed (or the electronic module switched on) allowing the current in the primary to start to flow.

The nature of the coil is to resist sudden change in current. Therefore, it takes time for the current to reach its maximum level. During the initial surge of current, a magnetic field starts to grow in strength. As a result of this growth, a voltage is induced in the secondary which has the opposite polarity and little energy.

Because of this, the primary current is seen in the secondary.

Distortions in this area can assist the evaluation of the coil condition, point condition, etc. Generally, those components affecting the primary circuit.

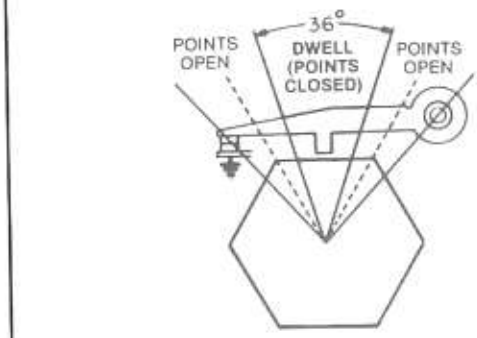
As the primary coil winding becomes charged with current, the growth of the magnetic field slows down. This can be seen by the gradual weakening of the voltage oscillations at this point.

5. Dwell

Once the engine points have closed (or the electronic module is on) the time until the next cylinder firing will be termed dwell.

This time is when the primary coil current is seeking its maximum current level.

FIGURE 8



ANALYZE THE SECONDARY

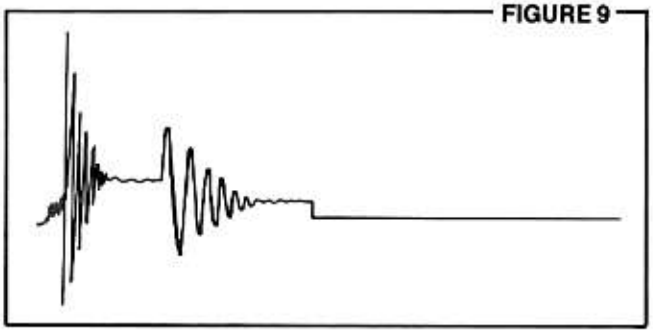
1. How high is the plug voltage demand with respect to the rest of the cylinders.
2. What is the slope, if any, length and condition of the firing line.
3. Can we get "rid" of the remaining energy before the points close.
4. How is the coil build-up
5. Do the points close and remain closed.

The conditions of the secondary circuit are typically the result of the individual cylinders or cylinder conditions. Problems effecting ALL cylinders in the secondary are usually caused by the primary circuit.

INTERPRETATIONS

Arcing Points

FIGURE 9



The point open area is not a clean break. Evidence of current flow across the breaker contacts is demonstrated by the erratic oscillations existing just prior to the first high oscillation.

Some of the primary energy is lost in the arc across the points. Usually, with this condition, the height of the first primary oscillation is lower than normal.

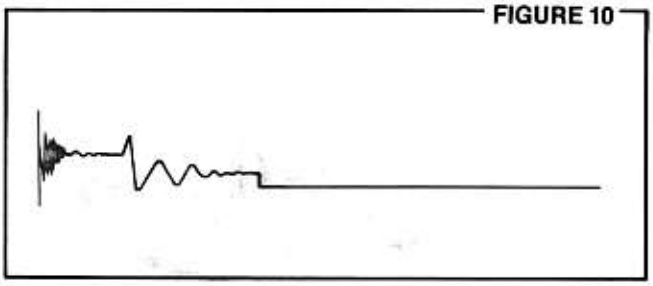
As a result of this condition, the spark timing will be delayed slightly, since the secondary voltage doesn't reach a high enough level to fire the plug until the primary current is completely blocked.

Also since the primary energy is slightly reduced due to the arcing condition, the firing time may also be reduced.

REPLACE THE POINTS AND CONDENSER.

Primary Resistance

FIGURE 10

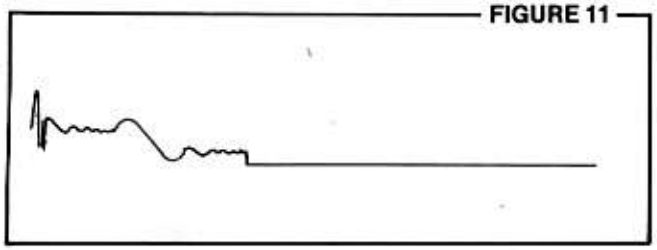


The first oscillation is considerably reduced as a result of lower than normal primary current. Consequently the amount of energy is also lower. Generally, with reduced height of the first oscillations, the number of following oscillations will be fewer.

CHECK THE BALLAST RESISTANCE, COIL RESISTANCE, IGNITION SWITCH AND BATTERY VOLTS.

Coil/Condenser

FIGURE 11

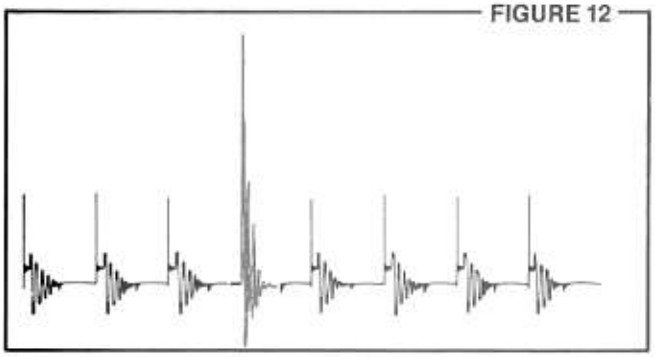


This pattern is typical of a shorted condenser or partially shorted coil. The remaining energy in the coil is discharged into the condenser. From the condenser, the energy should charge the coil again, however doesn't.

CHECK THE COIL OR CONDENSER.

Open Plug or Wire

FIGURE 12

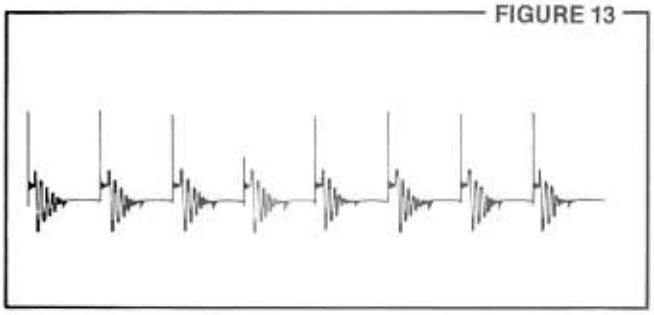


In the case of an open plug wire or open plug, there is no spark across the electrodes. Therefore, the plug voltage demand will be that of the available output voltage.

REPLACE THE PLUG OR PLUG WIRE.

Fouled Plug

FIGURE 13

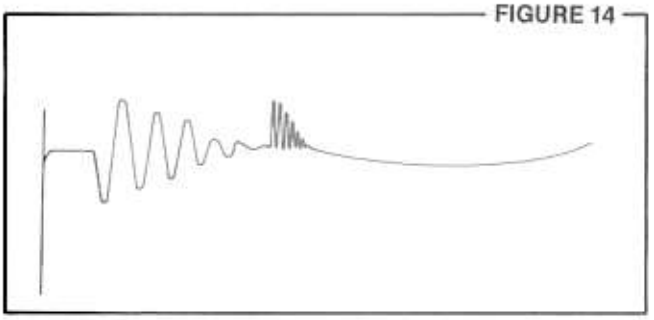


With a fouled plug the voltage demand will be no greater than what will be required by the rotor air gap.

REPLACE OR CLEAN THE PLUG.

Coil Polarity

FIGURE 14



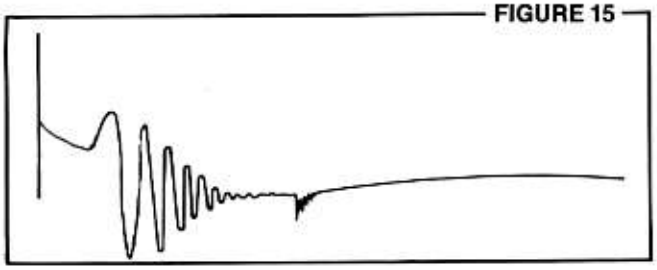
When the ignition coil wires have been installed backwards or the battery has been installed backwards, the secondary pattern will be displayed upside down.

An engine may still run with this condition, but the coil output efficiency related to the spark can be reduced up to 40%.

CHECK THE BATTERY POLARITY CONNECTIONS OR REVERSE THE COIL WIRE CONNECTIONS.

Secondary Resistance

FIGURE 15



One of the cylinders in the superimposed display shows the firing line higher than the rest of the cylinders and with a shorter duration. This is an indication of high secondary resistance. Factors affecting this condition are spark plugs, plug wires and mixture volume.

To further isolate the cause, the KV demand for the affected cylinder should be compared to the rest of the cylinders.

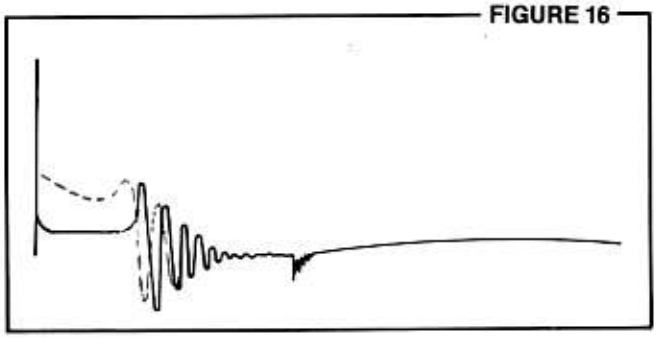
If the plug demand is greater, by 20% or more than the rest of the cylinders, then a strong suggestion of a wide plug gap or air leak to the combustion chamber exists.

Wide plug gaps require more KV to start the spark and use up the secondary energy quicker. While lean mixtures (air leak in this case) do not have enough conductive material (fuel) between the electrodes. Therefore the spark has to work harder and tires earlier.

However, if the KV demand is relatively equal with the rest of the cylinders, then the likely suspects would be high resistance plugs or wire. It doesn't take much to start the spark, but the spark is quickly used up in heat across the resistance.

Intermittent Secondary Resistance

FIGURE 16



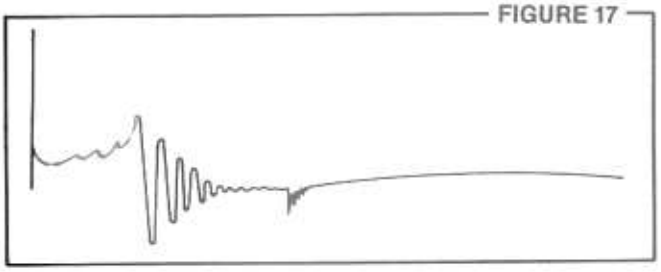
An intermittent display of secondary resistance is generally the result of sticky valves.

This erratic condition causes the fuel mixture to become momentarily lean when the valve hangs open. Consequently the fuel mixture becomes less conductive. The major difference between this condition and that of the one above is that with a component failure the problem is always there while with a sticky valve the display of resistance is only there some of the time.

Usually an oil change will correct the problem. However, that depends on the age of the engine and the extent of the problem.

Floating Valves

FIGURE 17



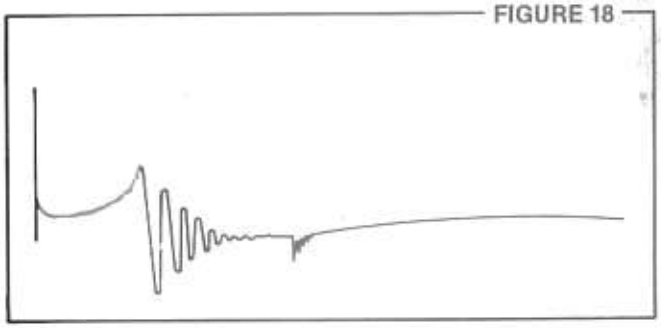
Floating valves tend to act up only at higher engine RPM.

A condition as above is most likely the result of fuel starvation. As the valves tend not to seat while the engine RPM is high, fuel flow and compression is disturbed. As a result the resistance to the spark increases as the spark duration extends.

CHECK COMPRESSION AND CARBURETION

Internal Resistance

FIGURE 18



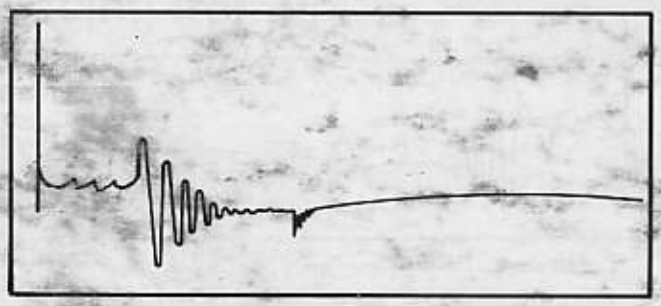
If the condition as shown above exists at ALL engine speeds, then it is not likely the cause of high RPM valve floataion, but more likely due to wide plug gaps. As the spark begins the resistance to the spark increases as the fuel is burning (less conductive volume).

In either of the two pattern examples above, the condition can be the result of the EGR system. At lower engine RPM the EGR valve is open and recirculates a percent of burned exhaust fuel while at higher RPM's the EGR valve may be staying open.

Under these conditions the conditions will be COMMON to ALL cylinders. If the problem is common to only once cylinder or some of the cylinders, then analysis as in the above examples will apply.

CHECK EGR OPERATION AND PLUG CONDITION

Firing Line Turbulence

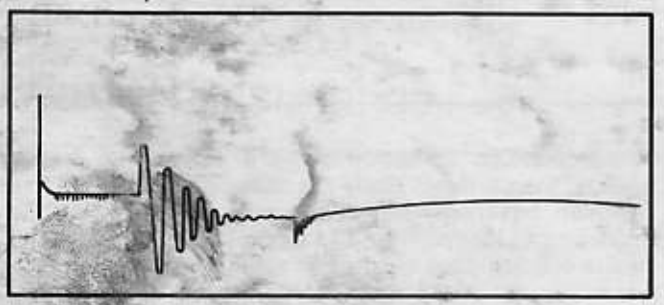


This condition can be caused by high compression or turbulence. The erratic condition along the firing line is a result of the spark blowing out and restarting.

Generally, this is not a problem with high compression engines, since the shape of the piston and the amount of "squeeze" can cause mixture turbulence or resistance.

However, on lower compression engines it may indicate a valve malfunction or excessive carbon build-up on the piston.

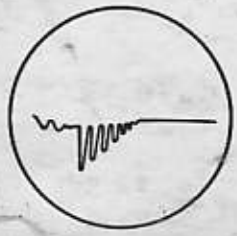
Rich Fuel Mixtures



The hairlike condition showing at the bottom of the firing line is a result of high conductivity (rich fuel). The spark occurs easier and as the fuel moves in and out of the electrode gap, the voltage necessary to sustain the spark reduces.

This condition is usually characterized by a lower than normal plug demand and a longer than normal spark duration. Don't confuse this condition with a fouled plug.
RESET IDLE MIXTURE ADJUSTMENTS

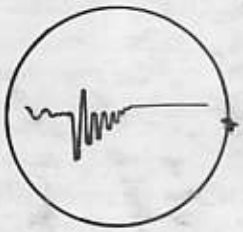
Points Close



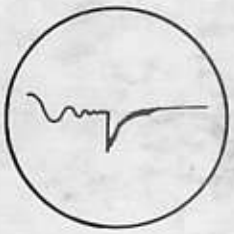
When the points close a build up of primary coil current is reflected in the secondary pattern.

Typically a minimum of 3 oscillations should be noted at this point, any deviation from the normal coil build-up can be seen with close examination of this area.

LOOSE CONNECTION
The poor connection can be anywhere in the primary circuit when the symptom wanders all over the dwell. If it is steady, the problem is related to the engine points.



BOUNCING POINTS
Usually acting up at high speed. The points do close properly, but momentarily open and charge up the condenser.



DEFECTIVE COIL
When coil build-up oscillations have been reduced or "killed", a likely defective coil condition exists.

PITTED POINTS
May or may not coincide with arcing points. Produces erratic or intermittent build up of primary coil current.

With all engines, proper operation depends on ignition, fuel, and compression. The absence of any of the three is detrimental to efficiency. Your analysis should always keep these requirements applied directly to the "scope picture."